Fluid transport at the nano- and meso- scales : from fundamentals to applications in energy harvesting and desalination process

Results in Brief

Confinement that frees innovation in nanofluidics

The interactions of solids and liquids are fundamental to natural processes and practical applications, but the realms of hard condensed matter and nanofluidics have rarely crossed paths. EU-funded research has demonstrated the value of harnessing the nanoscale quantum effects resulting from a marriage of the two.

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Nanoscale materials exhibit exotic properties not seen in bulk forms of the same materials, in part due to their very high surface areas compared to their volumes. Many applications leverage this, building on the unique electrical, chemical, optical and magnetic properties of primarily solid nanomaterials. The EU-funded NanoSOFT project has harnessed the quantum effects that emerge from nanoscale fluid transport confined in solid-state materials. Its pioneering outcomes challenge our current understanding of fluid transport at the nanoscale and pave the way for a new era of innovation.

A pioneering set-up to test theoretical predictions

Fluid transport at the nanoscale has been studied indirectly for over 50 years. Examples in nature abound, from the way plants absorb and distribute water and nutrients to the kinetics governing the ion flow through cell membrane channels during neurotransmission. Only in the last couple of decades has nanofluidics emerged as an important field of its own. Surpassing a critical level of confinement at the molecular scale can give rise to non-classical or quantum effects that may have important impact on fluid transport.

Until now, there was no experimental equipment to test theoretical predictions and model validity. “My transmembrane and trans-pipette nanotube device is the only set-up for investigation of fluid and ion transport through individual nanotubes made of different materials under different forcings – voltage drop, pressure drop, concentration gradient and combinations of these. My optical set-up pushes the flow measurement resolution to three orders of magnitude lower than the previous state of the art,” explains NanoSOFT coordinator Alessandro Siria of the French National Centre for Scientific Research and École normale supérieure.

Revisiting osmotic energy

Nanofluidics could play a significant role in our cleaner, greener energy future. One of the least known and cleanest forms of renewable energy sources is salt water, or, more precisely, fluids of differing salinities. It has long been known that a river flowing into a salty ocean releases energy in the form of heat.

Harnessing the power of osmosis would enable an emission-free and secure supply of energy independent of geopolitical conditions. Several concepts are under development and estimates suggest that the power equivalent of 1 000 nuclear reactors could be generated by harnessing osmotic energy. However, technology for its conversion to electricity has faced challenges achieving the efficiency required for large-scale power production.

NanoSOFT outcomes have demonstrated that the non-classical, quantum nature of the confining materials can significantly affect fluid transport and resulting phenomena can be turned to our benefit. “We converted the osmotic energy with efficiency two to three orders of magnitude greater than current state of the art. Our start-up company, Sweetch Energy, will build on this to commercialise a novel class of nanofluidic membranes for osmotic energy conversion,” states Siria.

Continued work in this realm is complemented by testing how nanofluidic approaches can be harnessed in novel technologies for water purification and desalination. Very good things come in small packages, and NanoSOFT is using these to address some of the world’s greatest challenges in the energy and water domains.

Keywords

NanoSOFT, energy, fluid transport, nanoscale, nanofluidics, quantum, osmotic energy, flow measurement, Sweetch

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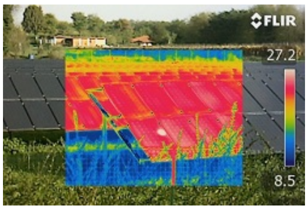

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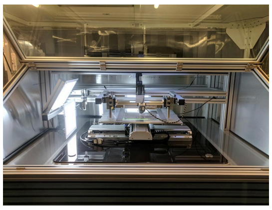

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